

MOUSE FOR COMPUTER CONTROL FROM THE JOYSTICK OF THE WHEELCHAIR

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Abstract: Becoming autonomous is one of the biggest challenges for many people with disabilities. Increasing their autonomy usually involves the use of both a wheelchair and any kind of digital assistant such as a computer or a tablet to communicate, to work or even only for leisure. In such situations, those people are forced to use two different human interfaces, one to move a pointer and the other to drive the wheelchair. A joystick is the most common commercial solution to control a wheelchair whereas there are many different adapted interfaces to emulate the use of a mouse. In this paper we propose the use of a wheelchair joystick as a human interface for electronic devices such as computers, tablets or smartphones. This designed system captures the motion of the joystick on a wheelchair to move the cursor or the pointer of any digital device including an USB port. It avoids any mechanical or electronic change in the joystick to keep its original safety and warranty. This non-invasive mouse is fast and simple to install. In addition, it is fully configurable to meet any potential user needs. Communication between the device and the computer (or any other digital assistant) uses the USB protocol, although it could be easily upgraded to a Bluetooth wireless connection. To verify the designed system it has been tested by different people: users with disabilities, and physiotherapists and other professionals in disabled people with positive results.

Keywords: Mouse control, Disabled people, Wheelchair control.

Introduction

The growing potential of digital electronic devices in the fields of communication, work, education or leisure makes the number of their users larger than ever. Many people with disabilities use them for tasks that otherwise could not be carried out by themselves. For instance, some speech-disabled people use a software speech synthesizer to communicate. Some other handicapped people use electronic devices to control their immediate environment (lights, air conditioning, automated doors, etc.) People with mental disabilities might use electronic gadgets for therapies that give them immediate feedback like encouraging words, music or graphics which is more motivating for them than traditional exercises with paper and pencil.

Most of these electronic units run graphical operating systems (like Windows, Linux or Android) which ask for the use of some kind of pointer. Commonly, keyboards, mice or joysticks constitute the user interfaces to these graphical operating systems. However, certain disabilities prevent the use of standard pointing devices, and require a full custom solution. Therefore, different disabilities require specific user adaptation which makes it impossible to design a universal human interface for the disabled.

Nowadays, different approaches to solve this problem can be found in the literature. The systems described by Sporka, Kurniawan and Slavík (2005) and Qidwai and Shakir (2012) uses a voice command to control the pointer. Here, the sound card in the computer is used to process the user's sounds which are converted into basic mouse functions: click, double click and axial movements. The key advantages of this method are its low power consumption and easy installation since no special or additional device is needed. In the field of speech recognition software tools like IBM ViaVoice or Dragon Naturally Speaking (www.nuance.com) can be found which are

intended to assist the user in typing texts. An alternative to this is visual technology, which has been studied. This method analyses the images captured by a camera in order to determine the user's gestures and head movements. While this technique requires few pieces of additional equipment it demands a high computational load (Tu, Huang & Tao, 2005 and Luqman, Ananta & Muda, 2011.) Kasun, Samarawickrama, Chandima, Chathuranga, Harsha and Abeykoon (2010) use computer vision and voice recognition technologies to facilitate the interaction of computers with handicapped people. To reduce the processing algorithms some systems use devices that are sensitive to non-visible light, such as infrared cameras. Adjouadi, Sesin, Ayala and Cabrerizo (2004) present a commercial system that tracks the user's pupil and lets him or her move the mouse. Other commercial systems from Prentke Romich Company (www.prentrom.com) capture the movement of the head by tracking the light spots emitted by a small device worn by the user which are then translated into mouse movements. Reflective elements or special glasses can also be used to create the light spots.

Systems based on physiological sensors can also be used to detect the intentions of someone by translating the electrical signals from the brain (electroencephalography, EEG) (Dong, Yuhuan, Hongzhi, Baikun, Yong & luk, 2009) or from the muscles (electromyography - EMG) (Changmok, Micera, Carpaneto, & Jung, 2008) into cursor movements. Unfortunately, the use of EEG or EMG to control a cursor is extremely complex because there is no simple way to separate the signals related to the mouse movement from the rest of signals (Pregenzer & Pfurtscheller, 1999), (Tarng, Chang, Lai & Kuo, 1997.) Moreover, these systems need to be periodically calibrated.

Inertial systems are also widely used. Tilt sensors (Chen, 2001), accelerometers and gyroscopes (Kim, 2002) make it possible to emulate a conventional mouse by sensing movements of different body parts (head, hands, body, etc.)

Despite the user can choose the system that best fits his or her needs between a wide range of solutions, he or she will have to deal with two problems, the intrinsic difficulty of getting familiar with the new pointing

device and plus the fact of using two user interfaces at the same time the joystick of the wheelchair and an adapted mouse. In this paper we propose the use of a wheelchair joystick as a human interface for electronic devices such as computers, tablets or smartphones.

Design requirements

Our device is intended for people, with reduced mobility, who use motorized wheelchair and are interested in using computers or similar equipment. It is designed to emulate the behaviour of a conventional mouse by sensing the movements of the wheelchair joystick and the clicks of external switches. The same switches that are used for environmental control or augmented communication can be adapted to our system.

In order to fit any user and offer an optimal user experience, the system has to:

1. Be non-invasive with the wheelchair and easy to install.
2. Adapt to the installation position and to the user mobility by means of calibration during its setup.
3. Neutralize the effects of the initial inclination when it is powered up. It should also be suitable for being installed up to 45°.
4. Be compatible with any wheelchair.
5. Offer two input connectors for customizable switches to emulate the mouse buttons. One of these inputs must allow the user to disable the cursor movement.
6. Be plug-and-play. The operative system has to automatically install it. Besides, the installation software has to allow the calibration for an optimal response.
7. Be customizable by its configuration software. Configuration options have to include the usual ones that operative systems offer for the mouse (cursor type, buttons behaviour, etc.) as well as special ones:

limitation of degrees of freedom in the axial movement and the filtering of unwanted movements such as trembling or shaking. The setup should be saved in the device, not in the PC, which will make it easier to use the same device with different PCs without repeating the configuration process.

System description

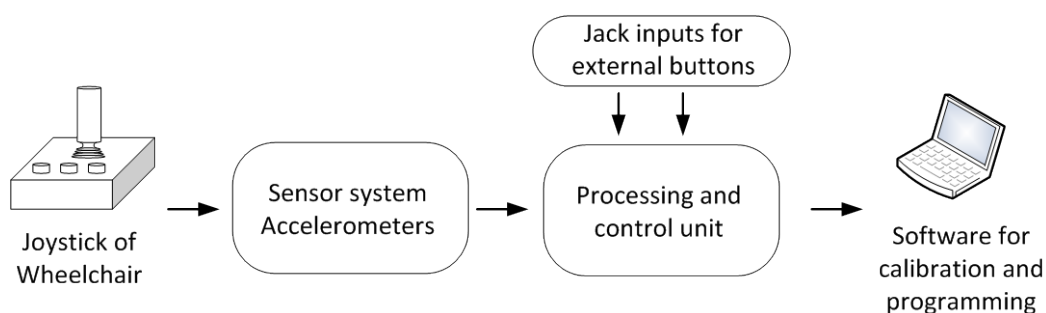
General overview

On the basis of the above objectives and requirements, we designed a low cost device intended to control the cursor of any computer, tablet, etc. provided it has a USB input connector, emulating a conventional mouse. The user moves the cursor by using the same joystick used to drive his or her wheelchair without interfering with this function.

As any modification on the electronics of the wheelchair would void its warranty, we based our design on the addition of an external biaxial accelerometer (ADXL202 or similar, www.analog.com) to sense the movements of the joystick.

Figure 1 shows the block diagram of our design and the main function of every subsystem. Details are explained in the following sections.

Figure 1. Block diagram of the mouse system



Data processing for pointer position calculation

The accelerometer used is a piezoelectric transducer for the measurement of dynamic acceleration (to sense the movements to control the mouse cursor) and static acceleration (that allows the control of the mouse by measuring the absolute tilt of the joystick). Its wide dynamic range makes eliminates the use of amplifiers. Only low-pass filters are needed to limit the bandwidth of the signal and reject the noise system.

One of the most important aspects for the measurement accuracy is how the accelerometer is fixed to the joystick. The sensor should be firmly and securely fastened, as any movement would cause the need for re-calibrating the system, with the associated inconvenience for the user. On the other hand, the fixing mechanism has to be simple, so users can install the mouse in a short time. This installation can be performed by an unqualified person (family, educator, ...). The idea is to remain installed in the wheelchair since the user can switch between the use of mouse and the control of the wheelchair. In order to ease the system use, this switching between the mouse and wheelchair control can be selected by an external button. For safety, this change must take place when the chair is completely stopped.

An analysis of different wheelchair models from several of the most popular manufacturers like Invacare (www.invacare.com), Otto Bock (www.ottobock.com) or Sunrise Medical (www.sunrisemedical.com) showed that all the levers in the joysticks have cylindrical supports of 38 mm in diameter. Given this, a simple solution is to place a disk around the lever where the accelerometer can be placed on (Figure 2.) This disk needs a hole for the joystick shaft to pass. It can be fixed to the lever by a self-tapping screw which allows its correct and easy installation on any wheelchair and in a few steps (Figure 3). The disk contains the accelerometer only, so it is necessary to route a cable for powering the sensor and for transmitting the acceleration signals.

Figure 2. Accelerometer sensor system in the joystick of the wheelchair

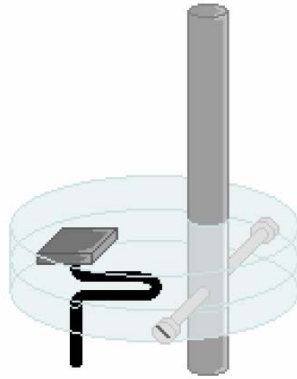
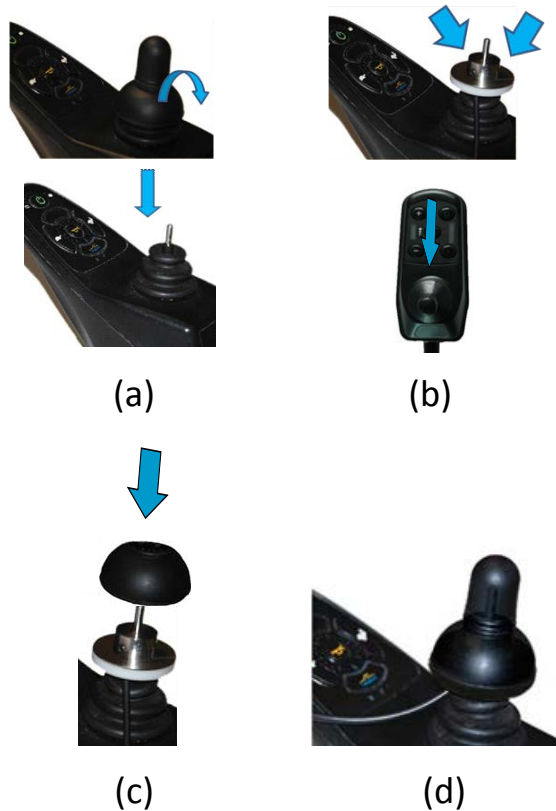


Figure 3. Mouse installation (a) Remove the handle and the protective cap of the joystick of the wheelchair, (b) insert the ring and tighten the set screw, (c) mount the protective cap and (d) reassemble the joystick of the wheelchair.



Specialized literature usually describes two methods to move the cursor over a display: absolute and relative positioning. In Evans, Drew and Blenkhorn (2000) there is an analysis about the advantages and limitations of both solutions. The absolute mode defines a correspondence between the position

of the joystick and the coordinates of the cursor. In this way, when the joystick is at its rest position the cursor is sent to the screen centre and when the joystick is pushed to the right-up end the cursor is sent to the right-up corner of the display. This method is more convenient for user interfaces based on the detection of the user's head position for people with a good control of their own movements.

However, we chose the relative positioning method for our design so joysticks are more efficient in this mode. The relative mode keeps the cursor moving while the joystick is being pushed. The position of the lever sets the direction and the speed for the cursor displacement. So, the movement of the cursor is defined by the deviation of the joystick from its rest position. Experimental tests showed that vibration, trembling or small unwanted movements of the user could result in small movements of the cursor. This annoying effect is avoided by defining a "dead zone" around the rest position. This way, while the joystick is kept in this area, its displacements are ignored and are not sent to the cursor. Experimental testing with potential users showed that the dead zone has to be, at least, 3.5° around the rest position. The user, however, can customize this value during the calibration procedure. In addition, the control unit processes the signal from the sensor in order to filter noise and avoid eventual oscillations of the cursor due to trembling or unwanted movements of a person with a disability, such as non-intentional hits or bouncing. To avoid the mentioned effects, the response of the sensor has been studied under the different conditions of actuation. The signals from the sensor have been sampled using a 5 ms period. These signals have been processed using average (mean filter) as well as median filtering. Average filtering (the average value in a set of measurements) is suitable for bouncing suppression, but the response of the cursor was not satisfactory under some configurations. Median filtering showed a better response and was selected to be implemented. Median filtering consists in sorting the measured values, dispose the ends of the interval and take the central value. The larger the number of samples, the better rejection of unwanted movements we will get, but, the bigger delay in the cursor movement. Tests have been performance in order to optimize the right number of samples.

The following figures present how unwanted effects have been reduced. Data of these figures are the typical results with one disability voluntary (male, 39 years old, with multiple sclerosis) obtained in one session. The results obtained with the same person in different days and sessions are similar. Figure 4 shows how small oscillations caused by a progressive movement are best rejected by a median filter. Figure 5 shows the efficiency of both filters to reduce bouncing when the user changes the sense of the movement. Figure 6 shows the same information when the joystick is hit and Figure 7 show the filtered bouncing when the joystick is suddenly released. These results validate the implementation of the median filtering.

Figure 4. Filtering of progressive signal.

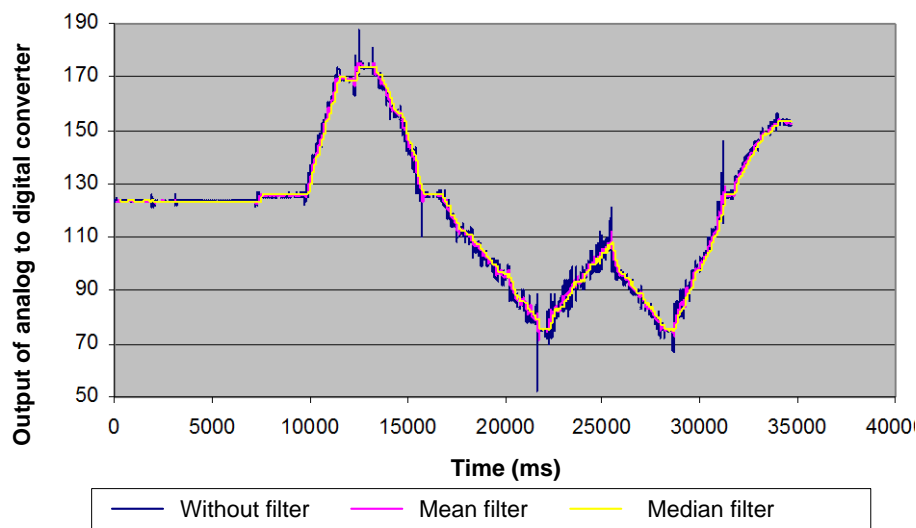


Figure 5. Filtering effect in motion for change of direction

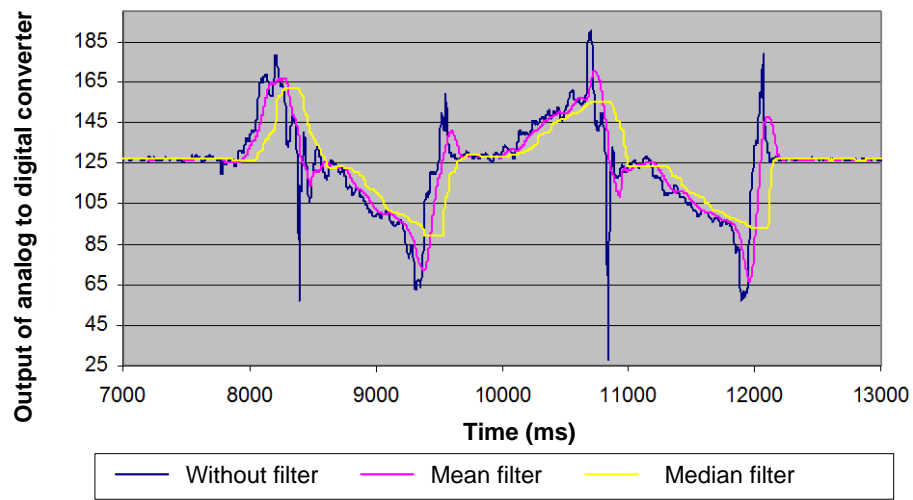


Figure 6. Effect of filtering strikes or violent actuation on the joystick.

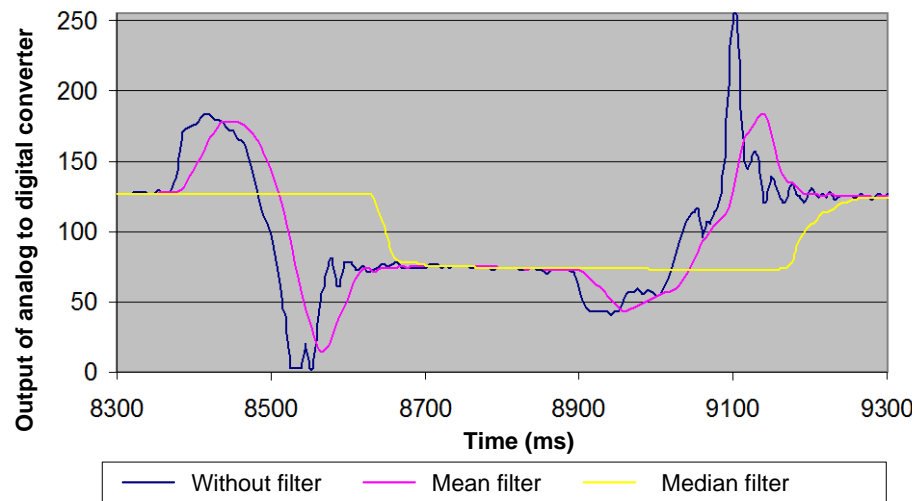
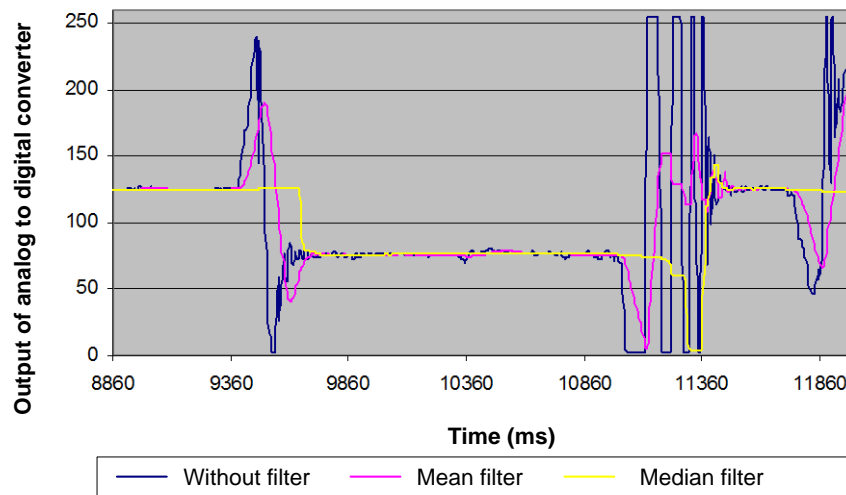


Figure 7. Filtering bouncing and joystick swings.

Customizable features

Besides the analog-to-digital conversion of the accelerometer signal and the reading of the push-buttons states, the control unit is responsible for the transmission of the data to the PC over the USB port. The control unit works together with the PC operative system adapting the movement of the cursor to the abilities of every user and saving the right configuration.

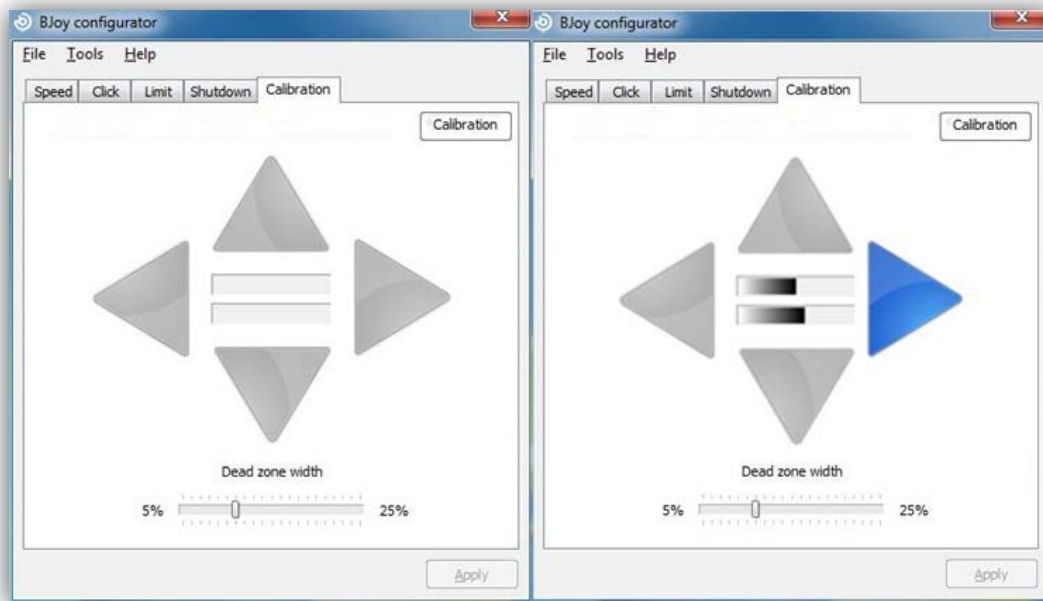
Different users suffer from different disabilities, which make it more or less difficult for them to deal with the pointing system. This is why we defined two different responses for the system, the basic and the advanced modes, in order to suit the abilities of every user.

When the basic mode is selected, the cursor moves at a constant speed as soon as the joystick is pushed out of its dead zone, no matter the inclination of the stick. According to the feedback from several users, the more convenient value for the dead zone is $\pm 13^\circ$ around the rest position and 5 pixels/s for the speed. Anyway, the users can customize both values to fit their personal needs. The basic mode offers the feature of snapping to four or two basic axis. That means that the cursor can move in any direction but it can also be restricted to move into the North-South or East-West directions (two axis restriction), as well as into the intermediate directions (four axis restriction). These restrictions are very helpful for people with

great difficulties to operate the joystick or for people with violent movements. On the other hand, this method is slow, since the speed of the cursor is constant. People with higher mobility abilities will find a proportional control for the cursor speed more comfortable. This is the more relevant feature of the advanced mode.

Selecting the advanced mode, the users will be able to configure the speed for the movement of the cursor. The speed will be proportional to the stick inclination, once it is pushed beyond its dead zone. The feedback from the users after the validation tests, gave us the convenient speed range and joystick sensitivity. The speed range was defined from 0 to 15 pixels, and the speed was set proportional to the stick angle with a recommended proportional constant of ± 0.33 pixels/degree. These parameters can also be customized in a configuration menu that the users will find in the configuration software to offer a higher adaptability.

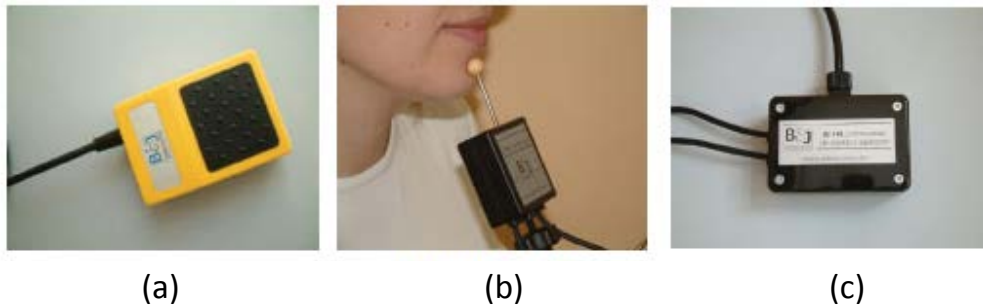
The reference position of the sensor its inclination at rest is a very significant issue. It is unknown a priori as it depends on how the device is installed, on the position of the joystick or even on the slope of the floor. This is why the system needs to be calibrated when the joystick is first activated. It needs to be calibrated only once, with the wheelchair at rest. This calibration is run on the computer by means of a simple GUI (graphic user interface) (Figure 4.) The calibration time is very short (<1 s) to avoid any inconvenience to the user.

Figure 8. System calibration software.

The calibration algorithm calculates the offset voltage when the inclination sensor is at rest (motionless joystick.) To find the offset value, we acquire and stored the value to be subtracted from later measurements. This correction of the initial position will allow the system work properly even if the initial inclination of the joystick is up to 45 °. In addition, unwanted movements due to psychomotor limitations of the user can be filtered. This can be done by adjusting the value of the variable "Minimum slope" that sets the threshold to detect any change in the position of the joystick.

The action associated to click buttons can be also customized. To emulate the buttons of a conventional mouse, four inputs using standard 3.5 mm jack connectors have been included. The user can plug any external switch such as pedal, chin or blow switches (figure 9) used by him in some other application (environment control or augmented communication, for instance.)

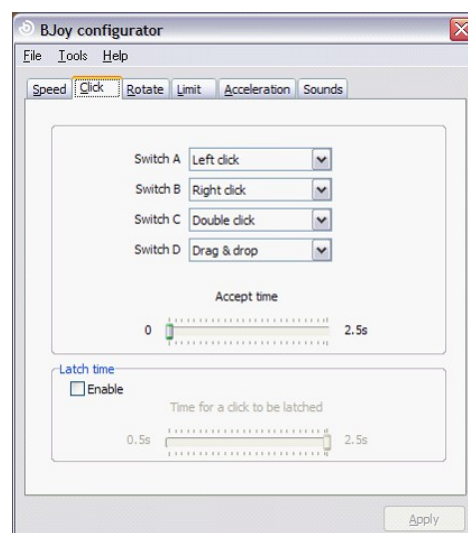
Figure 9. External devices to implement pressing mouse buttons. (a) with foot, (b) with chin, (c) by blowing.



The function of every switch is selected by the user from the options available in a drop-box list in the configuration software that is installed in the computer. (Figure 10). In addition, the user can customize some of the push-buttons features:

- a) Minimum duration for a valid push: This control lets the user select the minimum duration that the button has to be hold so that the function assigned to the button is run. This feature is intended to ignore unwanted clicks.
- b) “Long click”: this option enables the “hold on” function for any button. When any button is hold for a while, its function will be active even when the button is released. This way, actions such as drag and drop, or multiple selections can be done with a single click, with no need of holding on any button.

Figure 10. Software for external mouse buttons



User validation of the system

To verify that the designed system is suitable for controlling the cursor of any computer, it has been tested by more than 20 users. The first tests were performed with J. R., a 39 year old man with multiple sclerosis (figure 11). This disease has caused a severe mobility loss. As he cannot walk, he uses a wheelchair with a conventional mouse to control the computer he uses at work.

Figure 11. User with de BJoy Ring during the first test



The positive results of these first tests allowed for a second test. These were made in the Pont del Dragó centre (www.bcn.cat/pontdeldrago/ca/index.html). Pont del Dragó is a public school for people with physical disabilities. This centre aims to provide a better quality of life through the use of technology and communication as tools and strategies applied individually to facilitate greater personal and social autonomy. Here the system was tested on users with disabilities, children who study at the school and a centre staff group in a work session dealing with technical assistance. The group consisted of an occupational therapist, a physiotherapist, a speech therapist and the school's teachers. Later tests were performed on 7 new disabled aged between 14 and 55 years. In table 1 we present the data of the participants in these tests.

Table 1. Data of participants in the later tests

User	Genre	Age	Region	Disability	Previous experience
1	male	44	Barcelona	Multiple sclerosis	Experience in wheelchair control with manual joystick
2	female	45	Valencia	Tetraplegia	Experience in PC control with chin
3	male	55	Valencia	Amyotrophic Lateral Sclerosis	Experience in wheelchair control with manual joystick
4	male	33	Valencia	Cerebral palsy	Experience in wheelchair control with manual joystick
5	male	14	Galicia	Cerebral palsy	Experience in wheelchair control with manual joystick. Experience in PC control with n-abler system
6	female	30	Galicia	Acquired brain injury	Experience in wheelchair control with manual joystick. . Experience in PC control with Smartnav system (head control)

To draw the conclusions in the following lines we interviewed the users asking about the features of the adapted joystick that were useful for them. Their feedback can be summed up as:

- a) Having a system integrated with their own chair joystick add great value and convenience.
- b) The system increases their autonomy since they do not need someone else to activate any pointing device.
- c) The system prevents the device from falling, getting broken or out of the user's reach.
- d) It helps in allowing multiple users for the same device without making any changes or any specific configuration. In the same way, any user can use the same system to interact with many different computers or devices

- e) There is no need of having a dedicated and adapted PC for each user. Many people can share a conventional computer.
- f) The fact of being a plug and play device makes it easier to use while also increasing the user's autonomy as he or she does not need someone else help.
- g) Inclusion of the drag and double-click actions as a selectable function for the buttons makes its use easier and gives people higher agility in their activities.
- h) Some training is needed to get familiar with the system and take profit of its features, since the use of a joystick is different from a mouse.

This system can be upgraded to include wireless communication, such as Bluetooth, instead of using a USB cable (Casas, Quilez, Romero & Casas, 2006). Incorporating Bluetooth wireless communication presents the problem of power management. Charging or replacing the battery might be an issue for disabled users without someone else's help.

Conclusions

The design of the new system covers an existing gap in the field of disability assistance: an independent and easy to control user interface to digital assistant devices (such as computers, tablets) based on the joystick on a wheelchair. This noninvasive mouse is fast and simple to install. In addition, it is fully configurable to meet the need of any potential user. In addition, the configuration parameters are stored in the device, which avoids reconfiguration when the chair is connected to a different computer. Its features make this mouse a very useful aid for people with motor disabilities to maximize their own performance and to improve their quality of life.

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